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PARIS-SACLAY

# RG-C end of run and first look at physics

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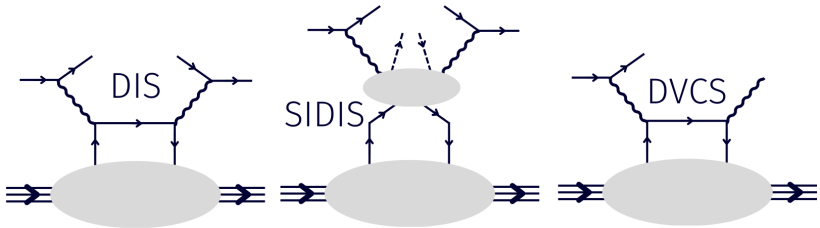
Noémie Pilleux - IJCLab Orsay

CLAS collaboration meeting - March 21, 2023

# Physics goals and motivation

RGC main feature: longitudinally polarized  $NH_3$  and  $ND_3$  targets.

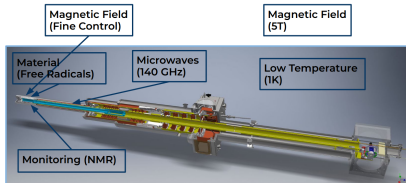
+ 10.5 GeV highly-polarized electron beam



Proposal	Physics	Contact	Group	Equipment	Energy (GeV)	Group	Target
E12-06-109	<a href="#">Longitudinal Spin Structure of the Nucleon</a>	Kuhn	485-120	Longitudinally Polarized target RICH (1 sector) Forward tagger	11	C S. Kuhn	$NH_3$ $ND_3$
E12-06-109A	<a href="#">DVCS on the neutron with polarized deuterium target</a>	Niccolai					
E12-06-119(b)	<a href="#">DVCS on longitudinally polarized proton target</a>	Sabatie					
E12-07-107	<a href="#">Spin-Orbit Correl. with Longitudinally polarized target</a>	Avakian					
E12-09-007(b)	<a href="#">Study of partonic distributions using SIDIS K production</a>	Hafidi					
E12-09-009	<a href="#">Spin-Orbit correlations in K production w/ pol. targets</a>	Avakian					

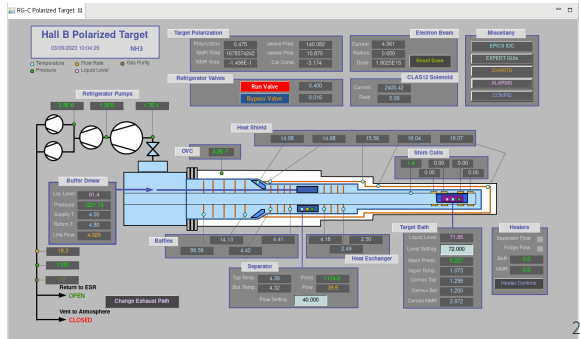
# Target overview

James Brock's talk for all target physics!



- Under 5T solenoid magnetic field
- Inside a 1K cryostat
- Samples are polarized with microwaves

- $NH_3$
- $ND_3$
- Background targets: empty, C,  $CH_2$ ,  $CD_2$  (mostly for dilution factor measurements)



# Target overview



A total of 75 target changes !

Many thanks to the **target group** for all the (very) hard work.

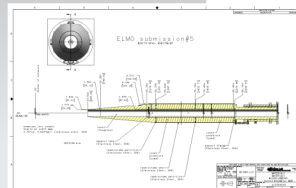
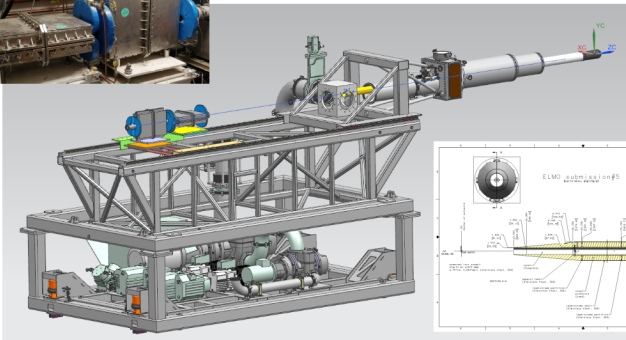
# Beamline

## The raster magnets

- Target is depolarized by radiation damage
- Beam is moved uniformly on the surface  
= **rastering**

## FTOn/ELMO configurations

- Beginning and end of RGC used the Forward Tagger
- Middle of the run used the ELMO Möller cone

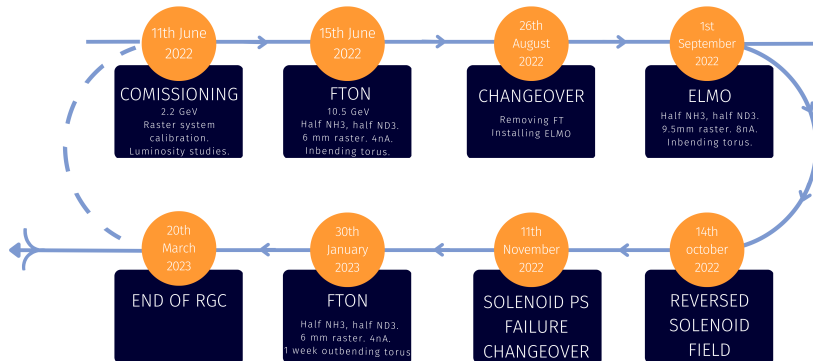


# Schedule

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# Schedule

Original plan: Run from June 8, 2022 to March 14, 2023 **120 PAC days**

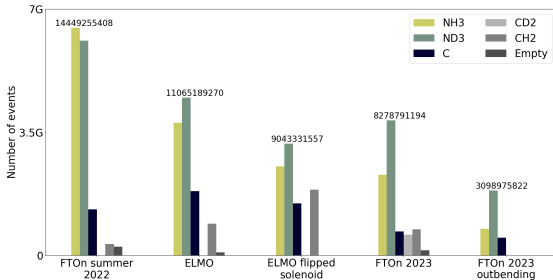


Many thanks to all Hall B engineers, technicians and experts for the several configuration changes!

# Summary for data taking

Period	Planned PAC days	Actual	Effective
FTOn 22	30 (15 $NH_3$ / 15 $ND_3$ )	35	28
ELMO	53	35	25.4
FTOn 23	37	25	
Total	120	95	

“Effective” : accounting for real beam availability.



- FTOn 2022 : 14G events.
- ELMO : 20G events.
- FTOn 2023 : 8G + 3G events (inbending/outbending torus).



## The target polarization

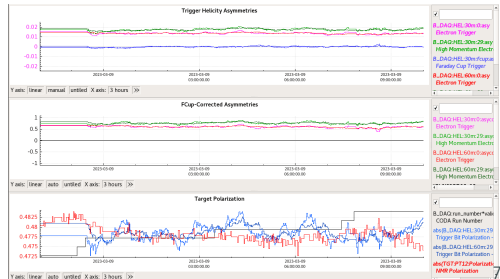
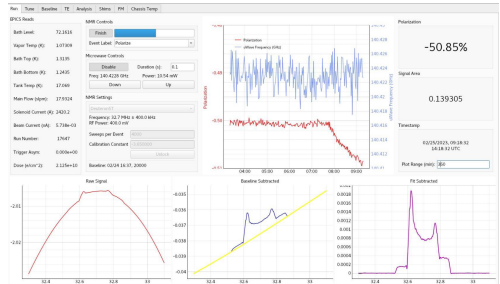
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# Monitoring the target polarization

Live monitoring:

- NMR coils around the target.
  - Continuously monitored.
  - Only a surface information.
- Trigger asymmetries.
  - Continuously monitored.
  - Normalisation extracted from DIS data analysis results.

Thank you to the target group and to Nathan Baltzell for all the time dedicated to this.



# Monitoring the target polarization

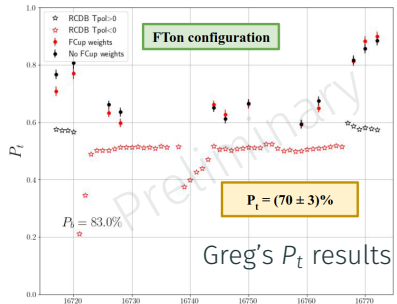
Within a few days: DIS analysis  
 $ep \rightarrow e'X$

- Comparing expected (model) and measured asymmetries.

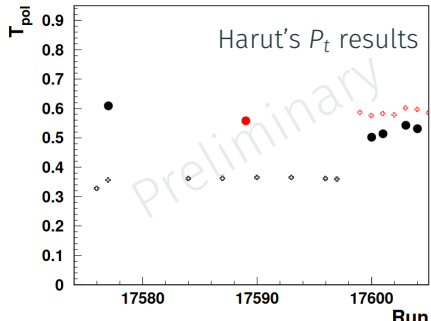
$$A = A_{th} \times P_b \times P_t$$

- Run by run measurement.
- Only reconstructing  $e^-$ : no need for full calibration of the detectors
- Used to normalize trigger asymmetries. Indicates when anneals could be needed.

Thank you to [Harut Avakian](#) and [Gregory Matousek](#)!



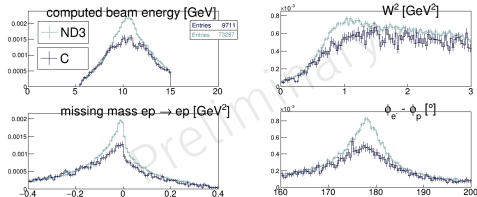
Greg's  $P_t$  results



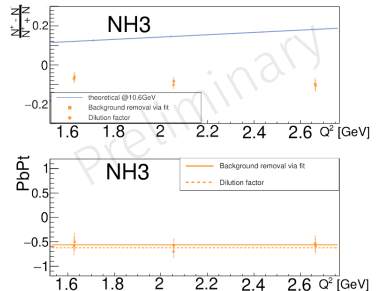
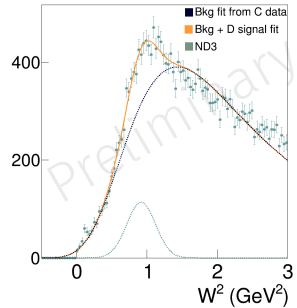
# Monitoring the target polarization

Longer term result: (quasi-) elastic analysis  $ep \rightarrow ep$

- Comparing exact theoretical asymmetry and measured value.
- Later results since it necessitates full cooking of fully calibrated data
- Necessary to integrate over several runs to get decent statistics.

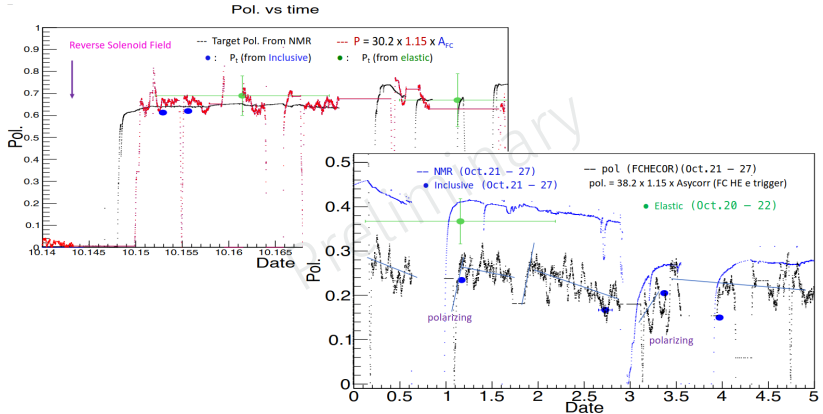


(Noémie Pilleux)



# Summary of target polarization measurements

Many thanks to Tsuneo Kageya for these studies.

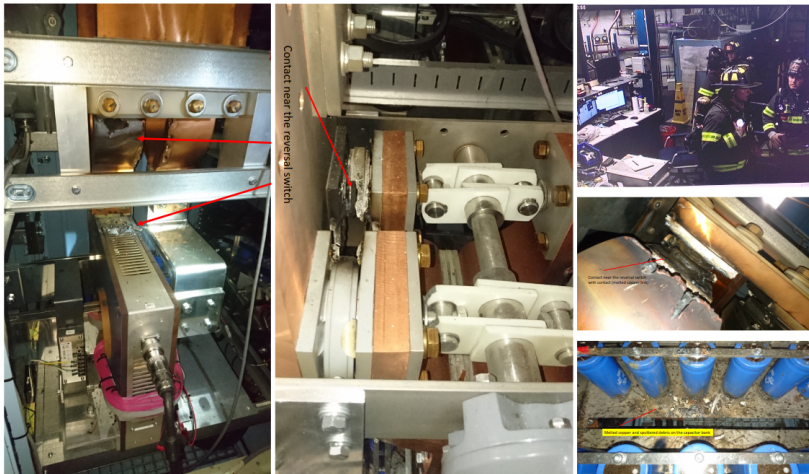


## Solenoid power supply

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# The solenoid power supply failure

11th of November 2022



# The solenoid power supply repairs

- November to January : incident analysis, repairs and testing.
- Failure was traced back to a firmware bug.
- January 30th: Thanks to the DC Power Group, Detector Support Group, Magnet Group, team from Danfysik, and Hall B technical staff all repairs and tests were successfully conducted and RGC restarted.

→ 80 days of work and repairs!





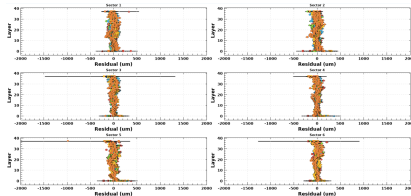
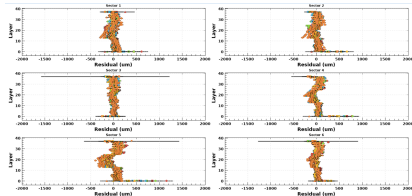
## Analysis status and preliminary results

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# Cooking and calibration

Calibrations are ongoing:

- Alignment has been completed for FTO on summer 2022 period.



- Beam offset calibration ongoing.

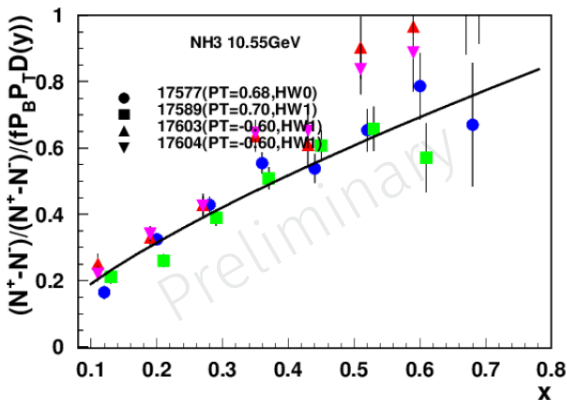
Some preliminary cooking has been done:

- Continuous cooking in HBT mode for target polarisation measurement.
- Preliminary cooking for analysis of a few runs in all configurations.

Thanks to Silvia Niccolai, Mohammad Hattawy, Kayleigh Gates!

# Preliminary results for Deep Inelastic Scattering

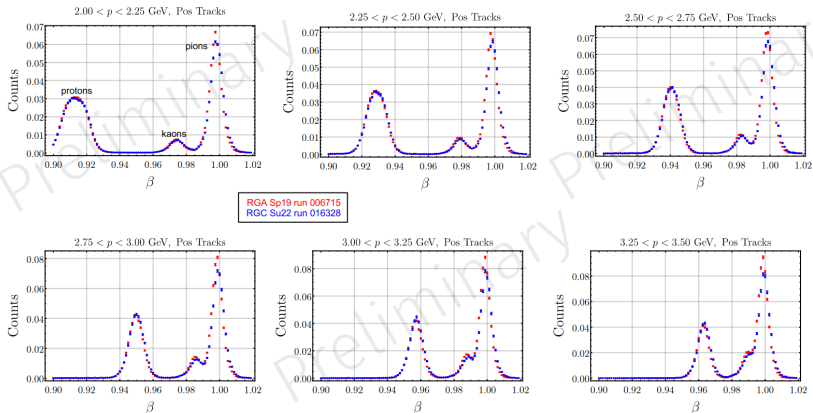
- Harut Avakian DIS analysis.
- Big picture: spin structure of the nucleon at high  $x$ .
- Interest of a polarized target: accessing  $g_1$ , polarized spin structure function.
- Observables:  $A_{||}$ , combination of  $A_1 \simeq \frac{g_1(x)}{F_1(x)}$  and  $A_2$ .



# Preliminary SIDIS PID comparison to RGA Data

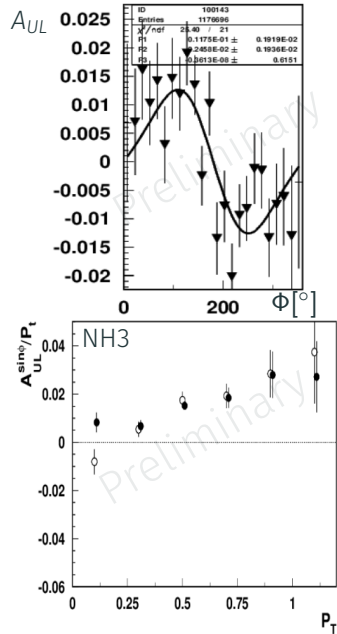
Timothy B. Hayward *epX* SIDIS analysis.

Preliminary HTCC and PCAL cuts give similar PID performances between RGA and RGC.



# Preliminary asymmetries from $e\pi^+X$

- Harut Avakian SIDIS analysis  $e\pi^+X$ .
- Big picture: 3D imaging of the nucleon, spin orbit correlations, TMDs.
- Observables: Single and double spin asymmetries
- Interest of long. polarized target: TMDs and Collins fragmentation function are involved in the TSA. DSA for flavour and polarization dependence of TMDs.



# Preliminary asymmetries from epX

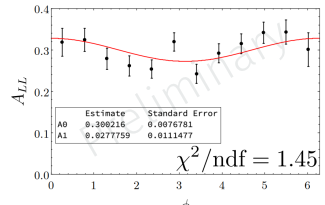
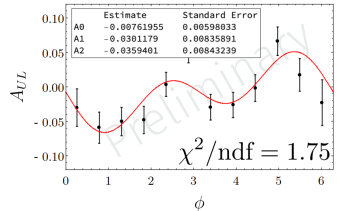
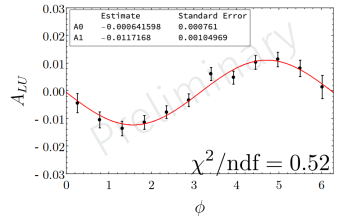
- Timothy B. Hayward SIDIS analysis.
- Big picture: 3D imaging of the nucleon, hadronization, Target Fracture Region
- Observables: Single and double spin asymmetries for Fracture functions .
- An interest of long. polarized target: DSA related to  $g_1$ , test of FrF formalism.

$$A_{LL} = \lambda_t S_L \frac{\sqrt{1-\epsilon^2} F_{LL}}{F_{UU,T}}$$

$$F_{LL} \propto \tilde{l}_{1L}(x, \zeta, P_T^2) = \int d^2 k_T \hat{l}_{1L}$$

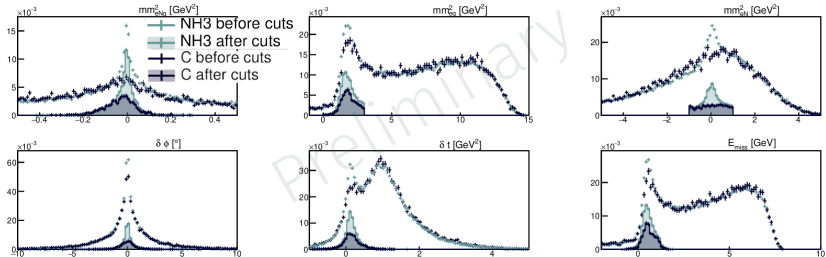
$$\sum_h \int \zeta d\zeta \int d^2 P_T \hat{l}_{1L} = (1-x) g_{1L}(x, k_T^2)$$

→ Timothy's talk Wednesday 14:50.



# Preliminary results for Deeply Virtual Compton Scattering

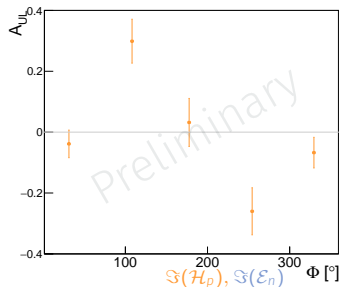
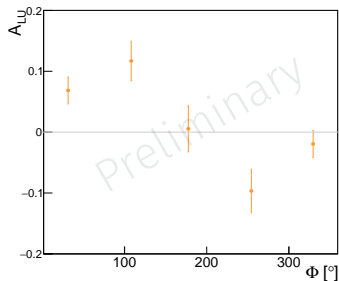
- DVCS analysis. In this presentation,  $ep \rightarrow ep\gamma$  in NH3 for 6 runs.
- Big picture: 3D imaging of nucleons, GPDs.
- Observables: Single and double spin asymmetries for CFFs.
- Interest of long. polarized target: Accessing GPDs  $\tilde{H}_p$ ,  $H_p$ ,  $H_n$ ,  $E_n$ .



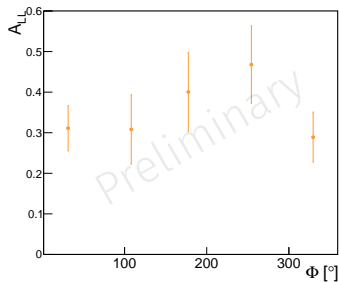
(Noémie Pilleux)

# Preliminary asymmetries for pDVCS (NH3)

$$\langle Q^2 \rangle = 2.5 \text{ GeV}^2, \langle X_{bj} \rangle = 0.23, \langle -t \rangle = 0.61 \text{ GeV}$$



(Noémie Pilleux)



$$\bullet A_{LU}(\phi) \simeq \frac{\overbrace{S_{1,unp}^I \sin(\phi)}}{\underbrace{c_{0,unp}^{BH} + (c_{1,unp}^{BH} + c_{1,unp}^I + \dots) \cos(\phi) + \dots}}$$

$$\Im(\widetilde{\mathcal{H}}_p), \Im(\mathcal{H}_p), \Im(\mathcal{H}_n)$$

$$\bullet A_{UL}(\phi) \simeq \frac{\overbrace{S_{1,LP}^I \sin(\phi)}}{\underbrace{c_{0,unp}^{BH} + (c_{1,unp}^{BH} + c_{1,unp}^I + \dots) \cos(\phi) + \dots}}$$

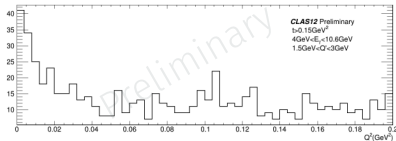
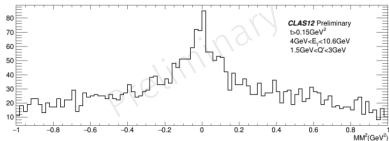
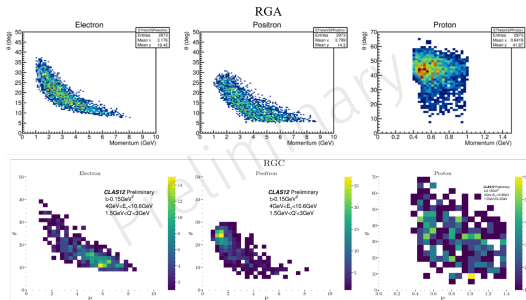
$$\Re(\widetilde{\mathcal{H}}_p), \Re(\mathcal{H}_p), \Re(\mathcal{H}_n)$$

$$\bullet A_{LL}(\phi) \simeq \frac{\overbrace{c_{0,LP}^{BH} + c_{0,LP}^I} + \overbrace{(c_{1,LP}^{BH} + c_{1,LP}^I) \cos(\phi)}}{\underbrace{c_{0,unp}^{BH} + (c_{1,unp}^{BH} + c_{1,unp}^I + \dots) \cos(\phi) + \dots}}$$



# Preliminary results for Timelike Compton Scattering

- **Kayleigh Gates** TCS analysis  
 $\gamma N \rightarrow \gamma^* N' (\gamma^* \rightarrow e^+ e^-)$   
 for 12  $NH_3$  runs
- Big picture: 3D imaging of nucleons, GPDs universality.
- Observables: Single and double spin asymmetries.
- Interest of long. polarized target: Accessing GPDs  $\tilde{H}_p, H_p$ .



# Summary

- After 10 months of running, RG-C ended yesterday!
- One of the big achievements of years of developing the longitudinally polarized target.
- Thanks to the very efficient repairs, we could run 95 PAC days out of the planned 120 PAC days.
- First physics results are promising.
- Many more exciting results to come soon with pass0 cooking.
- End of run party: TBA!

# Deepest gratitude to

- The target group, their work is the heart of RG-C: James Brock, Tsuneo Kageya, Chris Keith, Victoria Lagerquist, James Maxwell, Pushpa Pandey.
- All Hall B staff, technicians, engineers, detector experts for dealing with the endurance race that RG-C has been. In particular, many thanks to Denny Insley.
- Eugene Pasyuk for his PDL role, his guidance and his beamline expertise.
- All people that handled the solenoid power supply crisis: Probir Ghoshal and the magnet group, the detector support group, the DC power group and the review committee.
- Sergey Boyarinov, Valery Kubarovsky and Nathan Baltzell for rescuing, improving, maintaining DAQ and EPICS.
- All the RCs who didn't count their hours, sailed the experiment safely and kept shift takers content (and fed). Many thanks to all shift takers.
- The radiation control department for their help and availability.
- The software team who kept improving all tools, especially Raffaella De Vita.
- Silvia Niccolai for coordinating all the analysis and calibration, hosting all meetings and always being invested and excited in everyone's work.
- Mohammad Hattawy for all his efficient cooking and patient chef/sous-chef training. Kayleigh Gates, thank you for your availability and concern for a job well done.
- All RGC analysts mentioned previously for all the work showed in this presentation. Thank you to Samy Polcher and Derek Holmberg who also take part in this effort.
- Angela Biselli for designing ELMO.
- Sebastian Kuhn and Silvia Niccolai for carrying the RG-C program for years. Thank you for giving our community the opportunity to glimpse at exciting physics.
- Everyone who helped seeing RGC to its successful completion with all apologies if some names are missing.

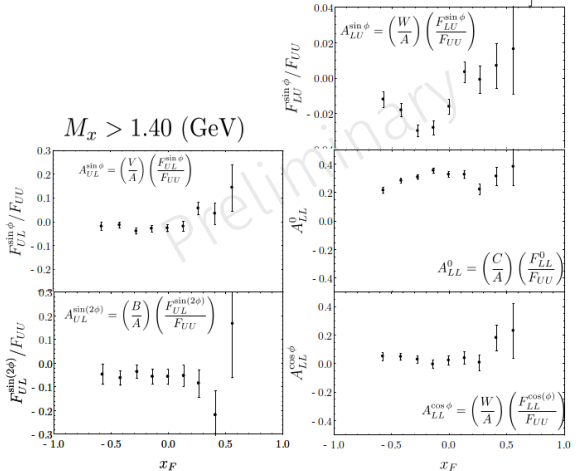
## Backup

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# Preliminary results from epX

- Asymmetries related to structure functions using depolarization factors.
- Structure functions related to FrF and fragmentation functions.

$$\frac{d\sigma}{dx dy d\zeta dP_T^2 d\phi_h} = \hat{\sigma}_U \left[ F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\varepsilon(1+\varepsilon)} F_{UU}^{\cos\phi_h} \cos\phi_h + \varepsilon F_{UU}^{\cos 2\phi_h} \cos(2\phi_h) + \lambda_t \sqrt{2\varepsilon(1-\varepsilon)} F_{LU}^{\sin\phi_h} \sin\phi_h + S_L \sqrt{2\varepsilon(1+\varepsilon)} F_{UL}^{\sin\phi_h} \sin\phi_h + \lambda_t S_L \sqrt{1-\varepsilon^2} F_{LL} + \lambda_t S_L \sqrt{2\varepsilon(1-\varepsilon)} F_{LL}^{\cos\phi_h} \cos\phi_h + S_L \varepsilon F_{UL}^{\sin 2\phi_h} \sin(2\phi_h) \right].$$



→ Timothy's talk on Wednesday 14:50.